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ABSTRACT

This unit of instruction deals with the physiological activities of plants. Attention is focused on the principles which underlie the activities of the typical green land plant. Emphasis is placed on biological processes such as photosynthesis, water transport, light responses, mineral nutrition, reproduction, and growth. The prerequisite for enrollment in the course is four Quinmester units in biology, and some experience in chemistry is suggested. The booklet lists the relevant state-adopted texts and states the performance objectives for the unit. It provides an outline of the course content and suggests experiments, field trips, and topics for student projects, discussion questions, and reports. Also listed are relevant films available from the Dade County Audiovisual Center. Reference books and Scientific American articles are recommended, and a master sheet is provided relating each suggested activity to the specific performance objectives. (JR)

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AUTHORIZED COURSE OF INSTRUCTION FOR THE QUINMESTER PROGRAM

PHYSIOLOGY OF PLANTS

5315.41

SCIENCE

(Experimental)

SE 017 621

DADE COUNTY PUBLIC SCHOOLS

DIVISION OF INSTRUCTION • 1971

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SCIENCE

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Written by William C. Gunn
for the
DIVISION OF INSTRUCTION
Dade County Public Schools
Miami, Florida
1972

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PHYSIOLOGY OF PLANTS

COURSE DESCRIPTION

This is a course about the activities of plants -- what they do and how they are equipped to do it. Attention is focused on a typical green land plant. It will be our purpose to analyze the principles which underlie the activities of plants. Emphasis is placed on the biological principles important to plants, such as photosynthesis, water transport, light responses, mineral nutrition, reproduction and growth.

ENROLLMENT GUIDELINES

The student must have completed four quinmesters of biology. A knowledge of chemistry will be helpful.

STATE ADOPTED TEXTBOOKS

1. Biological Sciences Curriculum Study. BSCS Green Version High School Biology. 2nd Edition. Chicago: Rand McNally and Co., 1968.

2. Biological Sciences Curriculum Study. Biological Sciences, Molecules to Man. 2nd Edition. Boston: Houghton Mifflin Company, 1968.

3. Biological Sciences Curriculum Study. Biological Sciences, An Inquiry into Life. 2nd Edition. New York: Harcourt, Brace and World, 1968.

4. Lee, Addison E., BSCS Laboratory Block. Plant Growth and Development. Boston: D. C. Heath and Company, 1964.

5. Jacobs, William P. and LaMotte, Clifford E. Regulation in Plants by Hormones. Boston: D. C. Heath and Company, 1964.

6. Abraham, Norman, et al. Biological Science, Interaction of Experiments and Ideas. 2nd Edition. Englewood Cliffs, New Jersey: Prentice-Hall, 1970.

RECOMMENDED TEXTBOOK

7. Ray, Peter M. The Living Plant. New York: Holt, Rinehart and Winston, 1963.

PERFORMANCE OBJECTIVES

The student will:

1. Summarize information on selected aspects of plant physiology from scientific journals.

2. Identify the major structural parts of a leaf.

3. Explain the function served by each part of the leaf.

4. Identify the structural characteristics of a root that perform the functions of storage, absorption, and anchorage.

5. Given a list of chemical elements, cite the role that each plays in the life of a green plant.

6. Develop a hypothesis based on observations and inferences drawn from plant activities.

7. Use data from plant experiments to make predictions.

8. Explain the flow of energy from the sun, through a living plant system, into an organic molecule.

9. Given a description of the works of various scientists, explain how the work of each scientist is related to the total concept of photosynthesis.

10. Identify terms relating to plant activities.

11. Demonstrate the ability to combine concepts, principles, and generalizations by designing an experiment to illustrate an activity of a green plant.

12. Identify the role of meristemic tissue.

13. Compare structurally and functionally tracheids and vessels.

14. Depict the events and factors involved in water transport in a land plant.

15. Cite the effects of auxins on plant growth.

16. State the conditions necessary for the operation of the <u>flow hypothesis</u> in phloem transport.

COURSE OUTLINE

I. The Plant Way of Life

A. The essential function of green plants - photosynthesis

1. Structural adaptations

2. Behavioral adaptations

B. Discoveries

1. Priestley's contribution

2. Ingenhousz's contributions

3. Lavoisier's discovery

4. de Saussure's contributions

C. Plant nutrition

1. Autotrophic

2. Heterotrophic

D. Organs of the plant

1. The root

a. Functions
b. Growth patterns
c. Nutrition

2. The shoot

a. Functions
b. Growth patterns
c. Nutrition

E. Vascular system

1. Functions of xylem and phloem

2. Arrangement of vascular bundles

3. Effects of girdling on plant conduction

4. Comparison of plant and animal transport systems

COURSE OUTLINE (Continued)

II. Plant Cells and Their Activities

A. The cell wall

1. Physical characteristics

2. Chemical composition

3. Functions

B. The cytoplasm and cellular metabolism

1. Respiration

a. Glycolysis
b. Citric acid cycle
c. Hydrogen transport

2. Cytoplasmic organelles and their functions

a. Mitochondria
b. Cloroplasts
c. Ribosomes
d. Endoplasmic reticulum
e. Vacuoles

C. The structure of plant tissues

1. Middle lamella

2. Plasmodesmata

3. Intercellular air spaces

D. Water balance in cells

1. Osmosis

2. Hydrostatic pressure

3. Roles of vacuoles in water balance

COURSE OUTLINE (Continued)

E. Structural specialization of cells

1. Parenchyma
2. Secondary walls
3. Pits
4. Fibers
5. Tracheids

III. The Photosynthetic Apparatus

A. Overall reaction

B. Comparison of photosynthesis and respiration

C. Oxidation and reduction in photosynthesis

D. Photosynthesis in the leaf

1. Structural and functional relationships
2. Adaptations for the absorption of CO_2

IV. Water Economy in Plants

A. Transpiration

B. Mechanisms of water transport

C. Water transportation in roots

V. Mineral Elements and the Life of the Plant

A. Macronutrients and their roles

B. Micronutrients and their roles

C. Absorption of minerals

D. Transport of nutrients within a plant

VI. Plant Growth and Development

A. Primary growth

B. Secondary growth

COURSE OUTLINE (Continued)

C. Regulation of growth

1. Tropic responses
2. Experimental evidence
3. Regulation of growth by auxins
4. Other regulatory factors

VII. Reproduction

A. Asexual reproduction

B. Sexual reproduction

C. Regulation of flowering

D. Mechanisms of photoperiodism

E. Temperature and reproduction

F. Hormones in plant reproduction

G. Germination of seed

H. Light responses in germination

EXPERIMENTS

BSCS Laboratory Block, Plant Growth and Development

1. Seed Viability (p. 1)
2. Volume Change of Different Seeds During Germination (p. 4)
3. Structure and Nature of Seeds of Different Plant (p. 4)
4. What is the Effect of Seed Coat on Germination? (p. 8)
5. What is the Effect of Temperature on Germination? (p. 9)
6. What is the Effect of Oxygen on Seed Germination? (p. 10)
7. What is the Effect of Light on Germination? (p. 11)
8. Measurement of Growth in Plants (p. 20)
9. Where does Growth Occur in the Plant Root?(P. 25)
10. What is the Importance of the Tip to Root Growth?(p. 26)
11. Do Cells Increase in Number During Growth? (p. 32)
12. What Do Cells Look Like During Growth? (p. 33)

EXPERIMENTS (Continued)

13. Do Cells Increase in Length During Growth? (p. 33)
14. Changes in Cells As They Mature During Growth and Development (p. 36)
15. How are Cells and Tissues Organized in Higher Plants? (p. 39)
16. Respiration (p. 44)
17. Photosynthesis (p. 49)
18. Mineral Nutrition (p. 52)
19. Enzyme Activity (p. 55)
20. The Effects of Auxins on Plant Growth (p. 59)
21. The Relationship Between A Growth Substance and Phototropism (p. 63)

BSCS, A Laboratory Block, Regulation in Plants by Hormones

22. Bioassay for Auxins in Coleus Leaves (p. 44)
23. Is the Growth of Roots Controlled by Hormones? (p. 65)

BSCS, Student Laboratory Guide, An Inquiry into Life, 2nd Edition

24. The Significance of Leaf Color (Inquiry 15-1, p. 96)
25. Leaf Structure and Function (Inquiry 15-2, p. 97)
26. The Pigments in a Leaf (Inquiry 15-3, p. 98)
27. Light and Leaves (Inquiry 15-4, p. 100)
28. Plants and Air (Inquiry 15-5, p. 101)
29. Gateway into a Leaf (Inquiry 15-6, p. 102)
30. Stems (Inquiry 16-1, p. 104)
31. Roots (Inquiry 16-2, p. 105)
32. Transportation in Plants (Inquiry 16-3, p. 107)
33. Flowers (Inquiry 17-1, p. 110)
34. Regulation of Growth in Plants (Inquiry 17-5, p. 119)

BSCS, Biological Sciences, Molecules to Man, 2nd Edition

35. Investigating Photosynthesis (p. 168)
36. Investigating the Production of Carbohydrates by Plants (p. 170)
37. Investigating the Effects of Varying Light on the Rate of Photosynthesis (p. 174)
38. Investigating Chlorophyll Pigments (p. 187)
39. Investigating Reproduction in Flowering Plants (p. 306)
40. Investigating Transport in Plants (p. 474)
41. Investigating Digestion in Plants (p. 521)

EXPERIMENTS (Continued)

42. Investigating Regulation of Growth in Plants (p. 557)
43. Investigating Light and Plant Stem Growth (p. 561)
44. Investigating Movement in Plants (p. 630)
45. Investigating the Behavior of a Plant, Mimosa (p. 752)
46. Investigating Carbon Pathways in Plants (p. 756)
47. Investigating Transmission, Reflection and Absorption of Light (p. 760)
48. Investigating Regeneration in Plants (p. 766)
49. Investigating a Plants Ability to Absorb Phosphorus Through its Leaves (p. 767)

BSCS, Green Version High School Biology, 2nd Edition

50. The Germination of Seeds, An Experiment (p. 8)
51. A Study of Environmental Tolerance (p. 255)
52. Bioenergetics, An Introductory View (p. 408)
53. Transpiration (p. 448)
54. Stomata and Photosyntheis (p. 450)
55. Rate of Growth, Leaves (p. 470)
56. Vegetative Reproduction (p. 582)

BSCS, Interaction of Experiments and Ideas

57. Enzyme Activity in Germinating Seed (Investigation 19, p. 172)
58. Isolation of an Enzyme (Investigation 20, p. 174)
59. Effects of Light on the Germination of Seeds (Investigation 22, p. 181)
60. Mineral Requirements of Sorghum Plants (Investigation 24, p. 184)
61. The Effects of Light on the Growth of Seedlings (Investigation 29, p. 237)
63. A Biological Assay (Investigation 30, p. 244)
64. Effects of Gibberelic Acid (Investigation 32, p. 253)

PROJECTS

1. The book by L. Machlis and J. Torrey, Plants in Action, published by W. H. Freeman Company, San Francisco, has many experiments that can be developed into projects without expensive equipment.

2. Try projects in plant tissue culture; see reference in Scientific American by P. R. White.

3. There are numerous projects with plant tropisms. Students can modify some of the classical experiments with their own experimental designs.

4. Try extracting and crystallizing enzymes from seeds at various stages of their development. Estimate quantitatively with chromatography.

5. Flowering in plants is determined by such environmental factors as temperature, nutrition and length of night or day. It has been demonstrated that flowering can be induced in the biennial Henbane under conditions in which the plant will not normally bloom, by using Gibberellic acid. Try GA on other plants.

6. Growth substances may be extracted from plants with a variety of solvents, then filtered and evaporated to dryness. Students can design many projects with the extracted precipitates.

7. Many factors have been suggested as the cause of abscission in plants including auxins, minerals and carbohydrates. Make quantitative tests for these substances by paper chromatography and colorimetry.

8. Carbohydrates are the precursors of amino acids in plants. Since carbohydrates are formed during photosynthesis, is there a corresponding increase in the organic acid content of the leaves? Design an experiment to find out.

FIELD TRIPS

1. U. S. Plant Introduction Station, 13601 Cutler Road

2. Everglades National Park

3. Fairchild Tropical Gardens, 10901 Old Cutler Road

FIELD TRIPS (Continued)

4. Redlands Fruit and Spice Park, Redlands, Florida
5. Matheson Hammock
6. Morton Collectanea, University of Miami
7. University of Florida Experimental Station, Homestead

REPORTS

Students can abstract from Scientific American articles listed in the references. These can be presented as written reports or as seminar type presentations.

SPEAKERS

Consult the Visiting Scientist Program, Florida Academy of Sciences, see brochure.

SPECIAL PROBLEMS

1. The course outline is based on the book, The Living Plant, by Peter M. Ray. Most of the emphasis is on the physiology of seed plants.
2. A variety of labs are suggested at many levels of sophistication. It would be impossible to complete all the labs within a quinmester. The teacher should choose those labs which are best adapted to their student's ability levels, time schedules, and facilities. Order materials in advance so that they will be available when needed.
3. This course, as written, does not mandate the curriculum. Hopefully it can be adapted to a variety of teaching strategies.

SPECIAL PROBLEMS (Continued)

4. References are included in BSCS Blue, Yellow, Green, and Interaction of Experiments and Ideas. A few copies of each in the classroom or resource center will be useful as reference sources.

5. The Scientific American references contain in-depth descriptions of most of the research contained in the course texts and outline.

6. Several reference sources should be available at all times. See list.

FILMS AVAILABLE FROM DADE COUNTY AUDIOVISUAL CENTER

1. Adaptations of Plants
   1-11069, 15', C

2. Algae
   1-11117, 16', C

3. Chlorophyll (Photosynthesis)
   1-30628, 28', C

4. Gift of Green
   1-30730, 20', C

5. Growth of Seeds
   1-02704, 14', C

6. Leaves
   1-30474, 28', C

7. Life of a Plant
   1-02269, 10', C

8. Liverwort, Alternation of Generations
   1-11057, 16', C

9. Patterns of Energy Transfer
   1-30527, 28', C

10. Plant Growth and Development
    1-30639, 28', C

11. Plant Reproduction
    1-30649, 28', C

12. Regulation of Growth
    1-30469, 28', C

FILMS AVAILABLE FROM DADE COUNTY AUDIOVISUAL CENTER (Continued)

13. Reproduction in Plants
I-11051, 14', C

14. Requirements for Plant Growth
I-30634, 28', C

15. Roots
I-30659, 28', C

16. Seed Germination
I-11104, 14', C

17. Simple Plants, Algae and Fungi
I-11115, 14', C

18. Stems
I-30654, 28', C

SUGGESTED DISCUSSION QUESTIONS

1. What are some of the reasons why there is usually very little correlation between numbers of stomates per unit of leaf and its rate of transpiration?

2. Why do lower leaves of a plant and the innermost shaded leaves wilt before the upper and outermost exposed leaves?

3. What method would you recommend for measuring the rate of photosynthesis of a bean plant growing in the field? Point out possible sources of error.

4. Explain exactly why a leaf appears green to the human eye.

5. Why does sweet corn soon lose its sweetness after being picked?

6. Why do starchy seeds decrease proportionally more in dry weight during germination than oily seeds?

7. Discuss the different kinds of combinations in which nitrogen is present in a green plant.

8. Cut stumps of certain species of trees on which there are no sprouts sometimes have been found to remain alive for years. What are some of the possible explanations?

SUGGESTED DISCUSSION QUESTIONS (Continued)

9. Why do radishes usually "go to seed" if planted in the late spring?

10. Describe the mechanism of xylem conduction. What kinds of nutrients are conducted in xylem and in what direction?

11. What is the principle net end-product of photosynthesis as a whole? Review the possible fates of this end-product. What are the main transportation and storage forms of carbohydrates and how is the photosynthetic end-product converted into these?

12. Describe the structure and adaptive significance of a leaf.

13. Review the life cycle of a flowering plant.

REFERENCES

Scientific American Articles:

1. Arnon, Daniel I. "The Role of Light in Photosynthesis." November, 1960.

2. Basham, J. A. "The Role of Carbon in Photosynthesis." June, 1962.

3. Butler, W. L. and Downs, Robert J. "Light and Plant Development." December, 1960.

4. Wald, George. "Life and Light." October, 1959.

5. Grant, V. "The Fertilization of Flowers." June, 1951.

6. Koller, Dov. "Germination." April, 1959.

7. Steward, F. C. "The Control of Growth in Plant Cells." October, 1961.

8. White, P. R. "Plant Tissue Cultures." November, 1950.

9. Biddulph, S., and Biddulph, O. "The Circulatory System of Plants." February, 1959.

10. Zimmerman, M. H. "How Sap Moves in Trees." March, 1963.

11. Biale, J. B. "The Ripening of Fruit." May, 1954.

12. Jacobs, W. P. "What Makes Leaves Fall." November, 1955.

REFERENCES (Continued)

Scientific American Articles:

13. Salisbury, F. B. "Plant Growth Substances." April, 1957.

14. Rabinowitch, E. "The Role of Chlorophyll in Photosynthesis." July, 1965.

15. Geulach, V. A. "The Rise of Water in Plants." October, 1952.

16. Naylor, A. W. "The Control of Flowering." May, 1952.

Books:

17. Bold, Harold C. The Plant Kingdom. Englewood Cliff, New Jersey: Prentice Hall, 1964.

18. Esau, K. Anatomy of Seed Plants. New York: Wiley, 1960.

19. Calvin, M. and Bassham, J. A. The Photosynthesis of Carbon Compounds. New York: W. A. Benjamin, 1962.

20. Galston, A. The Life of the Green Plant. Englewood Cliffs, New Jersey: Prentice Hall, 1964.

21. Goodwin, T. W. Chemistry and Biochemistry of Plant Pigments. New York: Academic Press, 1965.

22. Steward, F. C. ed. Plant Physiology. New York: Academic Press, 1960.

23. Colquist, S. Comparative Plant Anatomy. San Francisco: W. H. Freeman, 1959.

24. Bonner J. and Glaston, A. W. Principles of Plant Physiology. San Francisco: W. H. Freeman, 1952.

25. Melvin, R. M. Plant Physiology. New York: Reinhold, 1966.

26. Rogg, G. E. The Growth of Plants. Penguin Books, 1962.

MASTER SHEET--PHYSIOLOGY OF PLANTS

Course Outline	Texts	Experiments	Projects	References	Films	Field Trips	Objectives
I	#1. pp. 451-471 #2. pp. 465-467 #3. pp. 50-53 #7. pp. 1-8	25,26,30,41, 44,45,51	1	10	1,6,7,17,20, 23	2,3,4,6	1,2,3,6,7,9, 10,11,12,13
II	#1. pp. 381-384 #2. pp. 465-467 #3. pp. 50-53 #7. pp. 9-26	15,12,13,14, 26,31	1,2	6	2,17,18,24		1,6,7,10,11, 12,13
III	#1. pp. 426-436 #2. pp. 174-185 #3. pp. 474-480 #7. pp. 27-43	16,17,24,27, 28,35,36,37, 38,47,52,54	1,8	1,2,3,12	3,6,9,19,22, 24,25	1,2,3,4,5,6	1,2,3,6,10,11
IV	#1. pp. 447-449 #2. pp. 474-480 #3. pp. 281-295 #7. pp. 44-59	32,40,41,53	1	7,8,13	15,18,21,22, 24.25	1,2,3,4,5,6	1,4,6,7,8,9,10, 11,13,14
V	#1. pp. 234-236 #2. pp. 470-472 #3. pp. 287-303 #7. pp. 60-77	18,49,60	1		14,22,24,25	1,2,3,4,5,6	1,5,6,7,10,11, 14,16
VI	#1. pp. 466-470 #2. pp. 342-358 #3. pp. 317-320 #7. pp. 78-96	8,9,10,11,12,13, 19,20,22,23,34, 44,55,61,63,64	1		14,24,25,26	1,2,3,6	1,6,7,10,11,12, 15
VII	#1. pp. 595-599 #2. pp. 299-301 #3. pp. 309-328 #4. pp. 114-122	1,2,3,4,5,6,7, 21,33,39,42,48, 50,56,57,58	1,3,5	4,9,16	4,8,10,11,13, 16,24,26	1,3,5,6	1,6,7,10,11,15